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Interactions Between Tactics and Technology in Ground Warfare

E. W. Paxson, M. G. Weiner, R. A. Wise

A Report prepared for

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

Rand
SANTA MONICA, CA. 90406

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PREFACE

This is one of a series of Rand reports documenting a study of advanced employment concepts for ground force operations, sponsored by the Tactical Technology Office of the Defense Advanced Research Projects Agency (ARPA). The overall objective of the study was to develop new concepts for the employment of ground combat systems incorporating advanced technology, and to define and evaluate weapon systems for implementing these concepts.

The first report, R-2365-ARPA, *A Method for Evaluating Advanced Systems and Concepts for Ground Combat*, by E. W. Paxson and M. G. Weiner, describes the general method of the study and discusses specific steps with examples from the evaluations carried out to date. The method incorporates a three-dimensional terrain board, a computer model, and a series of analytic modules programmed for a hand calculator to assess the outcomes of various combat engagements.

The second report, R-2376-ARPA, *The Terrain Intervisibility and Movement Evaluation Routine (TIMER) Model*, by L. H. Wegner and M. G. Weiner, presents a detailed description and program listings of the computer model used in the evaluation method to determine the effects of terrain on visibility, firing opportunities, and servicing rates of the systems.

The present report furnishes a series of examples of interactions between tactics and technology that were observed in the combat evaluations conducted during the study. These examples form the basis for some general observations and speculations about tactical-technological interactions in future ground combat operations in Europe.

SUMMARY

The Advanced Employment Concepts study was initiated by the Tactical Technology Office of the Defense Advanced Research Projects Agency (ARPA). The purpose was to develop new concepts in the employment of ground combat systems incorporating advanced technology, and to define and evaluate weapon systems for implementing these concepts. Rand developed an evaluation method as a contribution to that study; it incorporates three tools: a three-dimensional terrain board; a computer model (TIMER) for determining the effects of terrain on the visibility of targets from defense positions, and thus for calculating firing opportunities; and a series of analytic programs or modules for a hand calculator that determine the outcomes of engagements.

One of the concepts examined in the Advanced Employment Concepts study was *distributed area defense*, which employs a network of small mobile units capable of concentrating firepower on enemy forces moving through the area. The units are of two types, one equipped with an advanced direct-fire system and the other with an advanced indirect-fire system.

The direct-fire system is a portable weapon resembling a bazooka. It fires a laser beam-rider missile. The indirect-fire system in the study is either of two versions. One version is a precision guided mortar system that acquires targets through a sensor elevated by a tethered rotor. The other is a precision guided missile that acquires targets through a sensor mounted on a telescoping pole.

Two evaluations were carried out using the Rand method. One involved the direct-fire system and the guided missile system; the other, the direct-fire system and the guided mortar system. In both evaluations, a superior enemy attacked the defense force. The play covered two or three hours of combat before the enemy reached his objective.

A major subject of interest in the evaluations was the interaction between the technical characteristics of the advanced weapon systems and their tactical employment. Such interactions were continually evident during the course of gaming combat situations on the terrain board,

notably as they affected the initial structure of the defense force, battle intensity, synergisms among the systems, communications, and enemy countermeasures. This report presents examples of those interactions.

The evaluations also led to a number of general conclusions and speculations about future ground warfare in Europe:

Combat intensity will be high because of advances in the lethality, mobility, and target acquisition capabilities of weapon systems.

Combat units will be smaller, to take advantage of their increased power and render them less vulnerable to enemy artillery or nuclear weapons.

Effective battle management will be critical to the efficient use of resources in the compressed space and time of high-intensity combat.

Technology will place greater demands on human capabilities as systems grow still more complex, specialized skills are required for their operators, and battle managers must work under extreme pressures.

Maneuver of firepower will become more important as further improvements in target acquisition and precision delivery make it faster and more effective to concentrate firepower from indirect systems than to shift the positions of combat units.

In wartime, tactical adaptations are likely to be more feasible than technological innovations, since high-intensity conflict may not last long enough to develop and deploy new or modified systems.

Major developments in tactics or technology will have a ripple effect on force structure and combat operations as the full implications of advanced systems or changes in tactics pervade the issues of how many of what types of capabilities should be in the force.

These observations are based on tactical and technological developments that affect three fundamental relationships in ground warfare: those between space and time, firepower and maneuver, and offense and defense. More than ever before, they call for an effective partnership between tacticians and technologists.

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I. INTRODUCTION

This report presents a series of observations on the interactions between tactics and technology in ground combat. It also presents some generalizations and speculations about future ground warfare in Europe. The observations and generalizations are based on two evaluations of advanced combat systems carried out as part of a study of Advanced Employment Concepts for ground operations, sponsored by the Tactical Technology Office of the Defense Advanced Research Projects Agency (ARPA).

The purpose of the overall study was to develop some new concepts for the employment of advanced ground combat systems, and to define and evaluate specific target acquisition and weapon systems for implementing these concepts.

Rand developed an evaluation method as a contribution to that study; it is described in a series of reports, of which this is the third. The method uses a three-dimensional model of a portion of the terrain along the West German-East German border (a terrain board); a computer model (TIMER) for determining the presence or absence of visibility (line of sight) between defense positions and targets, and the duration of that visibility; and a series of analytic modules or programs for a hand calculator. The terrain board made it possible to represent tactical situations in great detail.

Fine-grain representation of the tactical situation is considered necessary for exploring the relationships between the operational characteristics and tactical use of ground combat systems that incorporate advanced technology. This subject has often been neglected in the design of advanced combat systems; technical characteristics usually command most of the attention.

Figure 1 depicts the approach used in the study, the steps of which are reviewed here as background for the observations presented in this report.

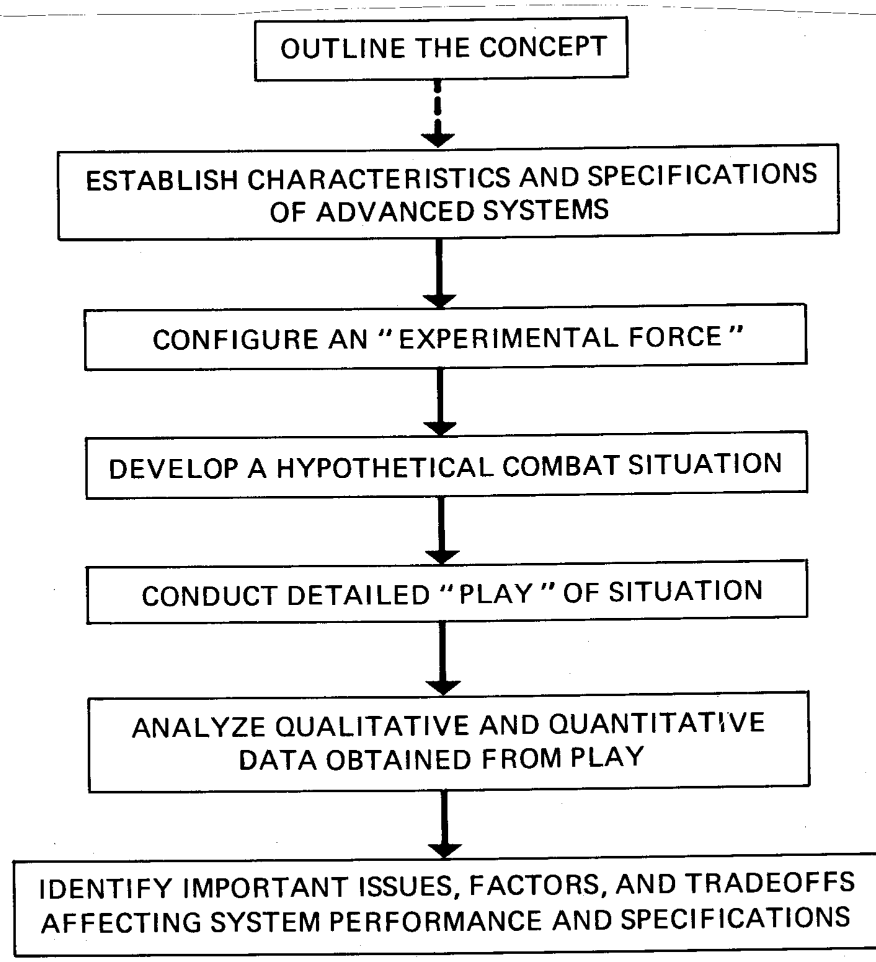

Fig. 1 — Basic methodological approach of Advanced Employment Concepts study

STEP 1: OUTLINING THE OPERATIONAL CONCEPT

The initial concept examined in the study was called Distributed Area Defense (DAD), for use in a European conventional conflict, under which an area was to be defended by a network of small mobile units equipped with precision delivered weapons. It incorporated the following features:

- A NATO response to a Warsaw Pact conventional attack seeks to limit enemy penetration of NATO; that is, it is a "forward defense" concept.

- o With warning of an impending attack, NATO defense forces move into forward positions in the border area between East and West Germany.
- o Maneuver in the border area is limited, and the emphasis is on the employment of small defense units distributed throughout the area.
- o The primary mission of the small units is to attrite enemy forces moving through the area.

The tactical plan of the defense uses available terrain in two ways. Small units equipped with *direct*-fire weapons establish defense positions to deny the enemy the use of forest roads or urban areas as cover for his advance. When forced into the open, enemy movements along main roads or across country come under attack by *indirect*-fire systems. The mobility of both the direct-fire and the indirect-fire systems permits them to move to new defense positions as the enemy continues his advance.

STEP 2: ESTABLISHING THE TECHNICAL AND OPERATIONAL CHARACTERISTICS OF THE ADVANCED SYSTEMS

The defense units were equipped with advanced systems for the precision delivery of direct-fire and indirect-fire munitions.

The Direct-Fire System

In the two evaluations carried out, the direct-fire system was a man-portable launcher resembling a bazooka that fired a laser beam-rider missile against either vehicles or aircraft. Table 1 lists its general characteristics.

The system requires acquisition of a ground or air target through the stabilized sight. The missile is launched and the target tracked as the missile rides the projected laser beam to the target. The warhead has an advanced shaped charge for use against tanks and wheeled vehicles or aircraft.

Table 1

CHARACTERISTICS OF THE DIRECT-FIRE SYSTEM

Range of missile	5 kilometers
Guidance	Laser beam-rider
Weight of total system	30 to 40 pounds
Weight of missile	20 pounds
Length of total system	50 to 60 inches
Length of missile	45 inches
Time of flight	2 seconds per kilometer
Sight	Stabilized with magnification
Warhead	Shaped charge

The Indirect-Fire System

The two evaluations used different precision guidance indirect-fire systems. The first evaluation employed a conceptual "guided mortar" system which acquired targets from a tethered, powered, elevated sensor platform on one vehicle and launched rounds from tubes on other vehicles. Table 2 lists its general characteristics.

The command and mortar vehicles are positioned near each other where they can deliver indirect fire on enemy vehicles in the open. The sensor package, mounted on a tethered rotor, is deployed from the command vehicle to the desired height, and the IIR sensor begins surveillance of possible target areas. On acquisition, target information

Table 2

CHARACTERISTICS OF GUIDED MORTAR SYSTEM

Command vehicle	Lightly armored, tracked
Sensor	Imaging infrared (IIR) on tether
Tether	Deployable to 200 meters
Computer	Sensor data processing
Mortar vehicle	Lightly armored, tracked
Mortar type	4.2-inch mortar tube
Mortar round	
Seeker	IR homing
Guidance	Ring of charges
Warhead	Shaped charge

processed in the command vehicle is transmitted to nearby mortar vehicles. The mortar tubes on the vehicles are automatically oriented toward the target and mortar rounds are then launched. The hot-spot seeker on the mortar round acquires a target. Terminal trajectory corrections are made by exploding appropriate small charges in a ring on the body of the mortar. The guided mortar system operation is illustrated in Figure 2.

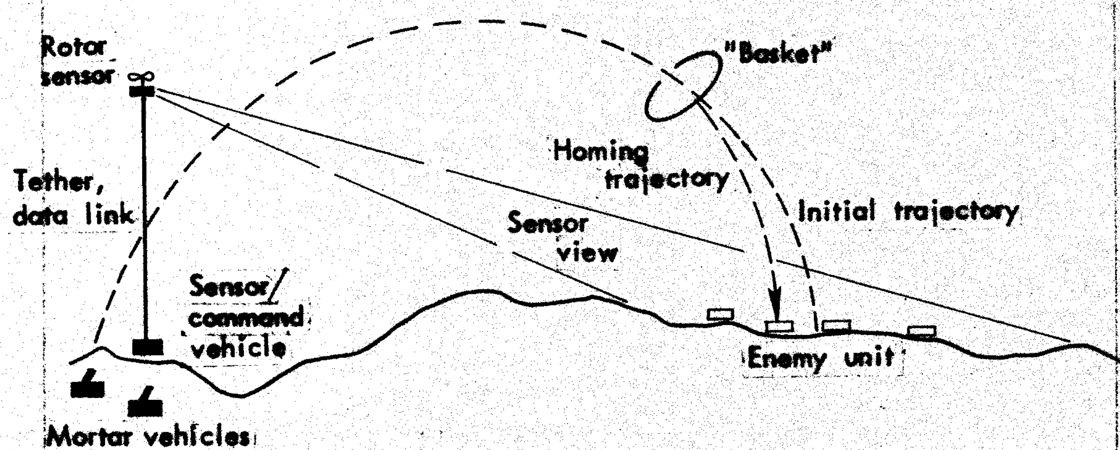

Fig. 2—Indirect-fire system schematic

The guided mortar system was used in the first of the two evaluations of the DAD study. Based in part on the results of this evaluation, another indirect fire system was proposed by the System Planning Corporation, Arlington, Virginia, under contract to ARPA. This indirect fire system, nicknamed TALLBOY for the evaluation (see Fig. 3), involved the following changes:

1. The target acquisition system, designation systems, and weapon systems were contained in one vehicle.
2. The tethered rotor was replaced by a telescoping pole, extendable to 30 meters above the armored vehicle. The

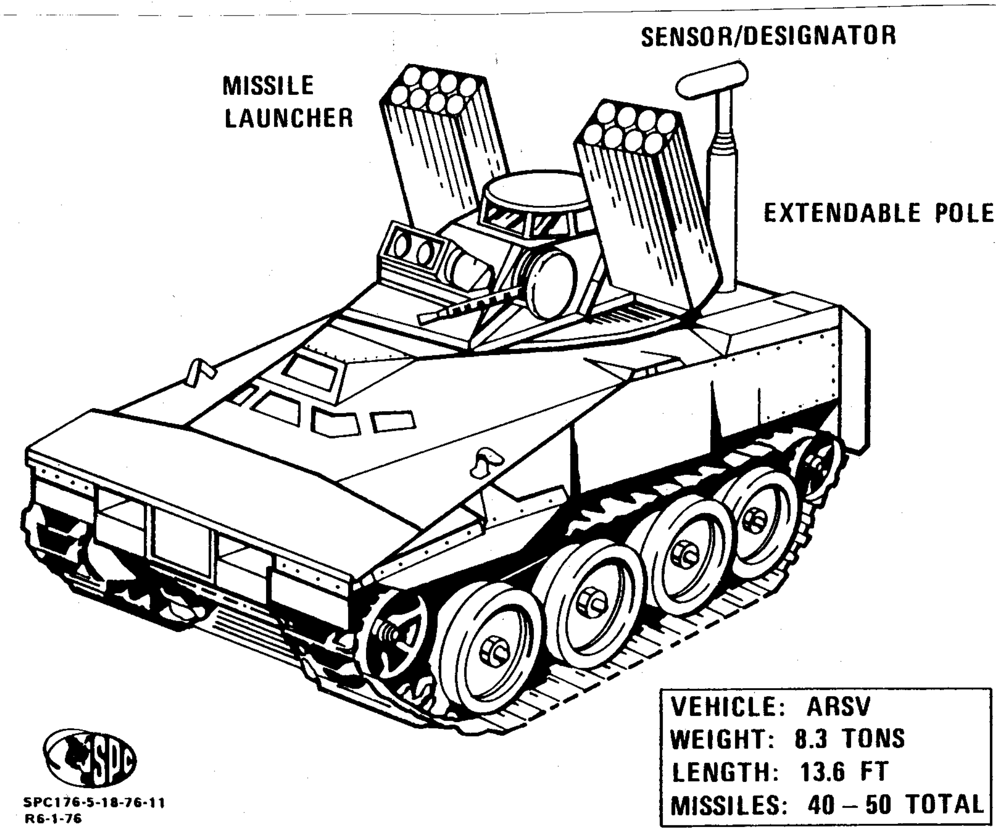

Fig. 3 — Tracked indirect-fire target acquisition/engagement system

pole and a detection/designation package consisted of a rotatable forward looking infrared (FLIR) sensor with a wide field of view (FOV) for target search and a narrow FOV for acquisition and fire control. The sensor package also contained a bore-sighted laser for weapon guidance to target.

3. The armored vehicle mounted ready racks of missiles which had a range of 5000 meters. Each rack held 8 to 10 missiles and the vehicle carried a single reload. The missiles used semiactive laser guidance and could cruise to the target at about 500 meters per second. The missile carried a three- to four-pound warhead.

The operational sequence for TALLBOY begins with target search and acquisition by the elevated sensor. Missiles are then launched from the racks, which are slaved to the sensor's azimuth. The launch is soft, using a pneumatic or spring mechanism. With the laser designator on target, the missile initiates search. On target acquisition, the missile fins deploy, the boost/sustain motor ignites, and the missile homes on the designated spot.

To implement the DAD concept, force organizations were designed for the advanced direct- and indirect-fire systems.

STEP 3: CONFIGURING AN "EXPERIMENTAL FORCE"

Configuring an experimental force is the term used in the evaluation methodology to describe the organizing of advanced systems into combat units.

Based on the DAD concept, an initial experimental force was configured for the direct-fire system and the guided mortar indirect-fire system. This was the basis for the first evaluation of the study. Subsequently, a second experimental force was configured with the same direct-fire system but with TALLBOY replacing the guided mortar system. Only the general characteristics of these two experimental forces are presented in this report.

The size of both experimental forces was set at approximately 900 men, roughly the size of an armored cavalry squadron or battalion task force. Both forces included 81 two-man direct-fire teams. Each member of the team was equipped with two of the advanced direct-fire weapons described above. To achieve high mobility, each team member had a motorcycle and carried the missiles in scabbards.

Within the 900-man limit, the experimental force of the first evaluation also included nine guided mortar sections, each with two sensor-command vehicles and three mortar platform vehicles to achieve a high volume of precision fire. In the experimental force of the second evaluation, TALLBOY vehicles replaced the guided mortar sections. The force consisted of the same number of vehicles (45), but all of them were TALLBOY vehicles. In addition to the advanced systems, the force also included an artillery battery, a headquarters section, a maintenance section, a truck supply section, and a medical section, while staying within the 900-man limit.

STEP 4: DEVELOPING A HYPOTHETICAL COMBAT SITUATION

The same combat situation was used for the two evaluations. This was an attack by an enemy motorized division reinforced with armor, artillery, and attack helicopters. The combat area was about 20 kilometers wide and 25 kilometers deep along the border between East and West Germany in the U.S. sector of responsibility. The mission of the enemy forces was the same: to reach an objective line about 20 kilometers deep without loss of momentum despite possible heavy casualties. The enemy plan of attack was also essentially the same: a period of artillery preparation followed by a ground attack by the six battalions of two lead regiments along six axes. Two additional regiments constituted the second attack echelon of the division.

STEP 5: CONDUCTING DETAILED "PLAY" OF THE SITUATION

The objective of the play was to collect data with which to evaluate the advanced combat systems. Major emphasis was on the interactions between the tactical play and the technological capabilities of the systems. Table 3 lists some of the questions on which data were collected.

Table 3

QUESTIONS ON TACTICAL-TECHNOLOGICAL INTERACTIONS

- Who sees whom at what distance for how long?
- How long does it take to bring fire to bear?
- How is fire allocated?
- How frequently are what weapons used against what targets and at what ranges?
- When, where, and why do units move?
- How do units coordinate with each other?
- What communications take place and when?
- How and when are units resupplied?
- How do systems complement each other?
- How vulnerable are these activities to enemy action?

To provide data on these questions, the evaluation method uses three tools: a terrain board, a large computer model, and a series of analytic modules.

The Terrain Board

The terrain board, pictured in Fig. 4, is a 1:10,000 three-dimensional model of the terrain in an area along the border. It provides a detailed "environment" of geographic features such as hills, forests, roads, and towns in which the tactical decisions on the positioning and movement of forces are exercised.

The Computer Model

The computer model, the Terrain Intervisibility and Movement Evaluation Routine (TIMER), also incorporates terrain data. It is used to determine such factors as intervisibility between elements of the friendly and enemy forces, the length of exposure, firing opportunities, and the like.

The Analytic Modules

The analytic modules are probabilistic programs for a hand-held calculator. They assess the outcomes of different types of engagements by the Monte Carlo method.

Figure 5 illustrates the basic structure of the play methodology.

Board play is a dynamic, minute-by-minute representation of the combat situation so that tactical decisions, maneuver, fire, target acquisition, and resupply of the enemy (RED) and friendly (BLUE) forces can develop naturally from the flow of battle.

For each activity and event that occurs, a set of logs provide the times, locations, moves, engagements, and outcomes. The quantitative and qualitative data generated during the play provide the material for evaluating the advanced systems (Step 6 of the methodology) and for identifying important issues, factors, and tradeoffs affecting system performance and specifications (Step 7). This report does not include the specific results of these two steps, but draws on them to illustrate particular points in the following sections.

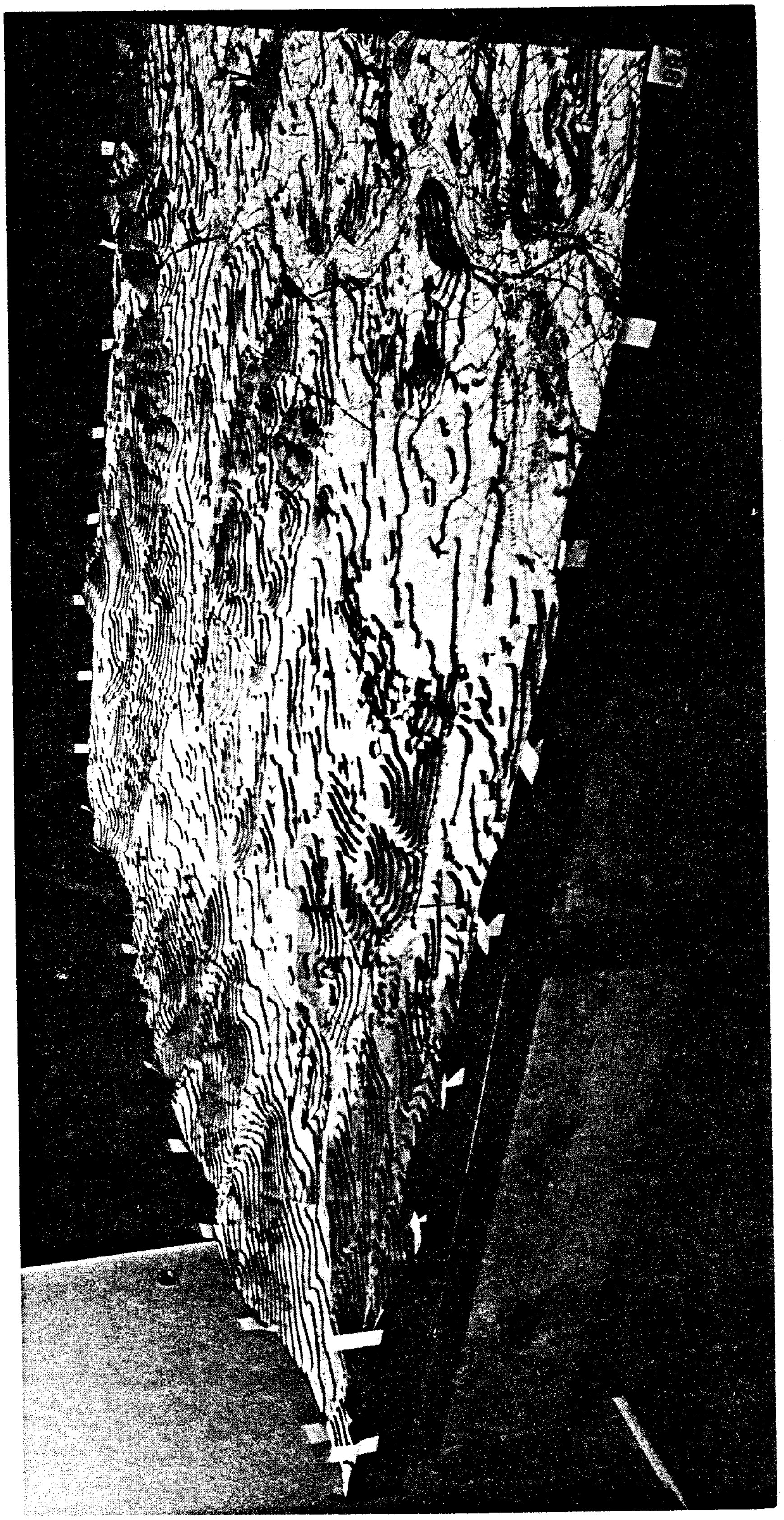

Fig. 4—Terrain board

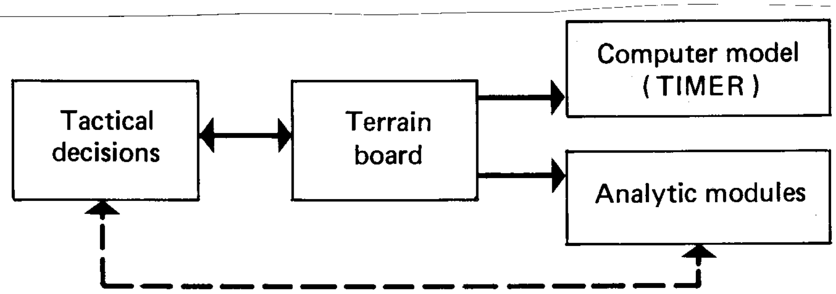

Fig. 5 — Basic structure of play method

Table 4 summarizes the major characteristics of the two evaluations. The play in these two situations, treated as two highly detailed *synthetic* histories of possible combat situations involving advanced weapon systems, provide the basis for the observations and generalizations discussed in the remaining sections of this report.

Table 4

CHARACTERISTICS OF THE TWO EVALUATIONS

Defense concept	Distributed Area Defense (DAD)
Defense tactics	Restrict enemy use of forest or urban cover; attrite forces moving in open areas
Direct-fire defense system	Man-portable launcher with laser beam-rider missile
Indirect-fire defense system	
Evaluation 1	Guided mortar; scatterable mines (artillery)
Evaluation 2	TALLBOY; scatterable mines (artillery)
Defense force	
Evaluation 1	Approximately 900 men; 9 mortar sections
Evaluation 2	Approximately 900 men; 45 TALLBOY systems
Attack force	Reinforced motorized rifle division; attack helicopters
Attack plan	Artillery preparation; two forward regiments on 6 axes; two second echelon regiments
Combat area	20 by 25 km along border between East and West Germany
Evaluation method	Detailed minute-by-minute play using terrain board, computer model (TIMER), and analytic modules for hand calculator

II. TACTICAL-TECHNOLOGICAL INTERACTIONS IN THE EVALUATIONS

The observations presented in this section deal primarily with the interactions between the tactics of ground warfare and the advanced technology of ground combat systems. They are based on the two evaluations conducted in the course of the study. As such, they are subject to the particular constraints and limitations of these evaluations. Specifically, these include:

- A particular concept for employment of the advanced systems, the Distributed Area Defense (DAD) concept.
- Two forces with specific advanced systems (a direct-fire system plus either a guided mortar system or the TALLBOY).
- A specific geographic area, a portion of the West German border in the U.S. sector of responsibility.
- A methodology that, like all evaluation methodologies of ground combat systems, embodies a large number of subjective components. These include the particular scenario, the organization of the experimental forces, and the tactical decisions of human participants on when, where, and why the forces maneuvered.
- Board play, which is a battlefield laboratory, not a battlefield, and the results should be judged accordingly.

In spite of these limitations, the evaluations offer an opportunity to see some of the possible interactions between ground tactics and advanced technology and to speculate on their implications.

The calendar time-scale to which the subsequent observations and generalizations of this report are considered relevant is limited to the next generation of advanced systems and their associated tactics. In some future period, completely different weapon capabilities may arise and the entire complexion of ground warfare may change, in which case new evaluations will be called for.

The interaction between tactics and technology is a continual and dynamic part of all combat. From the evaluations conducted for this study, only a few examples have been selected to illustrate specific points. The interactions presented in this section touch on:

1. Blue Force organization
2. Battle intensity
3. System synergism
4. Communications
5. Enemy countermeasures

BLUE FORCE ORGANIZATION

The purpose of the DAD concept is to attrite enemy forces by a network of mobile units distributed throughout the area to be defended. The concept requires an integration of technology and tactics in order to deliver a high volume of precision fire against enemy units.

Tactics

The tactical plan is to establish ambush positions along forest roads and around urban areas to restrict the enemy's use of cover and concealment in his advance. Units in these defensive positions employ direct-fire weapons. When forced into the open, enemy forces moving along roads or across country come under attack by a network of units employing indirect-fire weapons. As the enemy advances, the defense units leapfrog to new positions. The effectiveness of these tactics depends on the ability to deliver precise and concentrated fire on the enemy anywhere in the defense area.

Technology

The technology to implement these tactics is embodied in advanced precision guided weapon systems. These munitions potentially provide defense units with high lethality production in each engagement against enemy vehicles. Because of their high mobility, defense units can move to new positions to concentrate this lethality where required.

The technical characteristics of the indirect-fire systems, either the guided mortar or TALLBOY, drive the tactics in several ways. They provide broad coverage of the defense area because of their extended "reach" in both target acquisition and precision weapon delivery. The increased target acquisition capability results from the use of the elevated sensor. The increase in coverage obtained from the elevated sensor is illustrated in Fig. 6, which is based on calculations using the Terrain Intervisibility and Movement Evaluation Routine (TIMER) model. The figure shows, for the initial defense positions of guided mortars, the percentages of the six enemy attack routes forward of the positions that are visible as a function of the height of the sensor platform. The percentages apply only to those portions of the routes that are not covered by forest canopy or are not in urban areas.

Figure 6 indicates that at a height of 50 meters only about 40 percent of the routes open to observation are actually visible, largely because hilly terrain obscures parts of the routes. When the height of the sensor platform is increased to 200 meters, that percentage almost doubles, more routes can be seen, and more targets can be acquired and fired on.

The effect of increased route coverage on opportunities to engage targets can be illustrated by use of a metric called "firing opportunity" developed in the study. This metric takes two factors into account. The first is the fact that a target has to be seen long enough for a weapon system to acquire it, launch a weapon, and have that weapon travel to its target. This sequence is called the *system reaction time*. The second is the *velocity of the target*, since rapidly moving targets on short visible stretches may not be exposed long enough for the weapon system to bring fire to bear. Firing opportunities thus incorporate:

- The length of all the stretches of a route that are visible, depending on the height of the sensor;
- The reaction time of the weapon system from initial line-of-sight contact to weapon impact, and
- The velocity of the target.

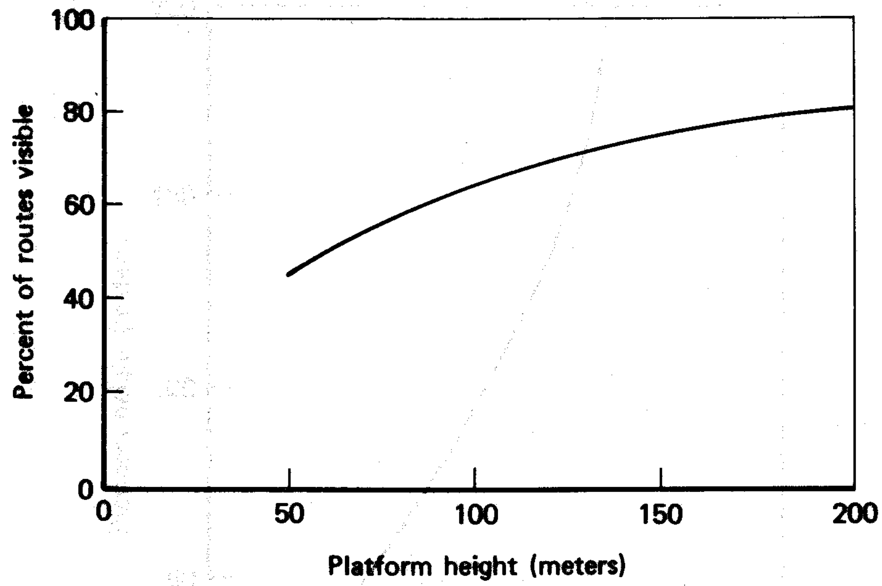

Fig. 6 — Visibility vs. platform height

As an example, if a target is moving at a speed of 15 kph (250 meters per minute) and the system has a reaction time of 120 seconds, then the system requires a stretch of 500 meters of unobstructed visibility to bring fire to bear. TIMER processes the terrain data in its data base and determines the number of such stretches, each of which constitutes one firing opportunity.

Figure 7 presents the number of firing opportunities for the chosen initial positions of the guided mortar sections as a function of sensor platform height, allowing for the above factors. It shows, for the conditions specified, that the number of firing opportunities nearly doubles as the height of the platform is increased from 50 to 100 meters, but increases little beyond that point.

This increase in the acquisition capability of the indirect-fire system is a major technological contribution to the DAD concept. It

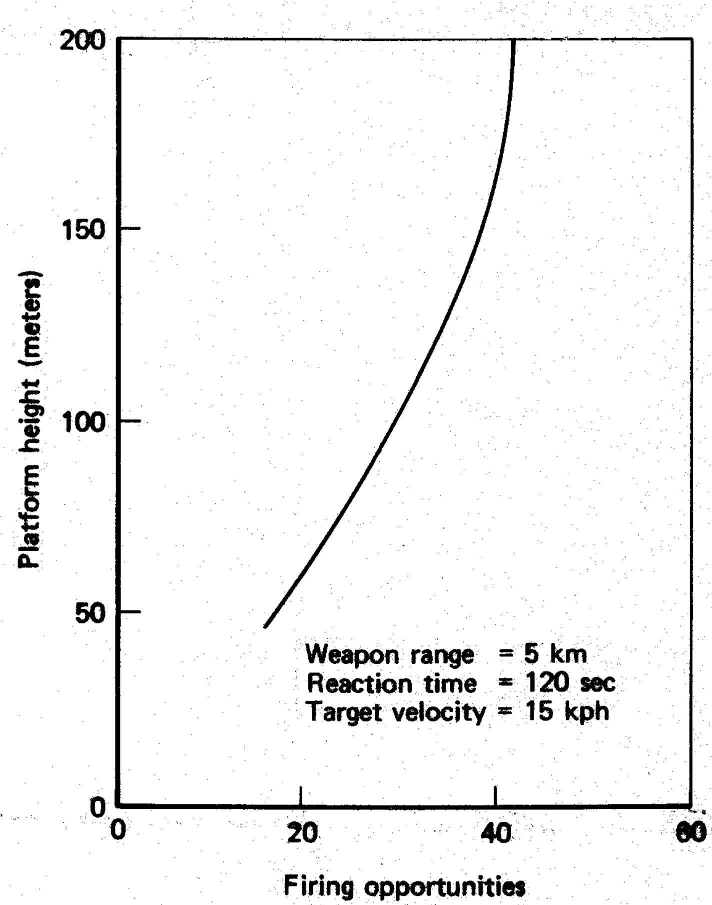

Fig. 7 — Firing opportunities vs. platform height

enables the system to engage targets from positions that are deeper and in defilade within the area to be defended.

Because of their reach, moreover, the elevated sensor platforms can be positioned so that the coverages of several platforms overlap. The mortar systems can then concentrate a large volume of fire on critical threat areas. Since the systems deliver precision fire to a range of five kilometers. they contribute to the tactics of the DAD concept.

The tactical plan and the available technological capabilities influence the combat organization of the defense forces. As used in this report, the term "tactics" includes both the tactical plan and the organizational structure of the combat units that implement it. The operational aspect is discussed separately at this point to illustrate the interdependence of technology, tactics, and organizational structure. Because a large number of mobile units are distributed throughout the defense area, they can displace to areas of high threat and concentrate fire on those areas. If the enemy is not using routes covered by the defense units, these out-of-action units can move rapidly to other areas, particularly if the units are small. These two factors--the multiplicity of units and the use of small units that can displace rapidly--are important determinants of the organization of the defense force. They are the basis for a force organization built around small, mobile, semiautonomous defense units. An additional factor, the potential reduction in the vulnerability of a force of small units, is also important. Any enemy who relies on the massive use of artillery will find it much more difficult to deal with numerous small, mobile units scattered throughout an area than with fewer, larger, less mobile units.

The DAD concept, then, illustrates how technology, tactics, and organization are interrelated. It incorporates:

- The *tactics* of denying the enemy the use of covered routes and forcing him into the open, where both the indirect- and direct-fire systems can attack him;
- The *technology* that allows long-range target acquisition and precision delivery of munitions, and also allows overlapping coverage that enables a high volume of concentrated fire; and
- The *organization* that supports the tactics and technology by being configured around small, mobile units that can be distributed throughout the area and move rapidly to high-threat locations.

The significance of the interdependence of tactics and technology and their influence on organizational structure transcends the specific example presented here. More and more technological advances in military systems are currently being achieved, but weaponry is only part of the picture; technologists must also be concerned--in peacetime--with how the implements will be used and who will use them.

BATTLE INTENSITY

The interactions of technology, tactics, and organization show up clearly during combat. In peacetime, "synthetic" combat as represented in the evaluations carried out in this study can provide some insights into the wartime situation. The evaluations provide a minute-by-minute description of the events that took place and can serve as a crude proxy for a real battle history.

Battle intensity was one important aspect of the combat situations that were enacted on the terrain board; in general, they were very comparable in their intensity. In both battles, the initial enemy force (RED) was a reinforced, motorized rifle division with substantial artillery support. The force contained 10,000 to 12,000 troops; it outnumbered, by more than ten to one, the defense force (BLUE) of approximately 900 troops. The battles took place in an area about 20 kilometers wide and 25 kilometers deep.

RED opened the battle with massive artillery fire lasting about 30 minutes, and then launched an attack along six battalion axes of advance. In the resulting battle, about 200 firing engagements occurred.

RED units reached their objective, a line approximately 20 kilometers into BLUE's territory, in two to three hours. During that time, RED lost a major portion of the combat systems (tanks and personnel carriers) of the two regiments of his first echelon. BLUE lost far fewer systems. Although the specific losses differed somewhat between the two evaluations, the exchange ratio in combat vehicles was between 10:1 and 15:1.

In general, battles may be called intense if substantial forces (regiments) are lost in a short period of time (hours) in a limited area. The two battles in this study were intense not so much in personnel casualties as in the losses of major combat systems such as tanks, TALLBOYs, and attack helicopters. These vehicles have small crews and not all crew members become casualties when the vehicles are hit. The heavy loss of major combat systems appears to be common in armored warfare, and may become typical of modern warfare as technology advances still further.

In both evaluations, tactics and technology contributed to battle intensity.

Tactics

The first tactical factor was the RED attack plan, which stressed pressing forward despite heavy losses. This operational imperative is consistent with stated Soviet doctrine for war in Europe. Soviet military writers emphasize seizing and maintaining the initiative and pressing the attack "resolutely," partly because of their recognition that a European war would be fought under the shadow of nuclear and chemical weapons and would change drastically if these weapons were used. From this view they derive the doctrine that momentum is crucial. Although rapid advance may entail heavy losses, Soviet military literature, citing historical combat data, argues that rapid advance will incur lower overall losses than slow advance for equal periods of extended conflict.

This Soviet view was reflected in the battle play. RED pressed his attack and suffered heavy losses. Hard-hit units were absorbed by other units as the advance continued.

In general, the attacker determines the intensity of combat and his decision, although influenced by technological considerations, is basically tactical.

Technology

BLUE's sophisticated weaponry was the other major factor in battle intensity, using attrition rate as one measure of intensity. BLUE's weapon systems acquired many targets through the extended reach and coverage of their elevated sensor platforms, and that advantage, combined with precision delivery of munitions, made the defense highly lethal.

Lethality, as a contribution to battle intensity, demands a close coupling of sensor information and rapid firing of weapons, to take advantage of the numerous targets acquired by the sensor coverage in a terrain where targets are frequently exposed for only a short time. Delays between target acquisition and delivery of fire reduce firing opportunities. This condition is reflected in Fig. 8, which indicates,

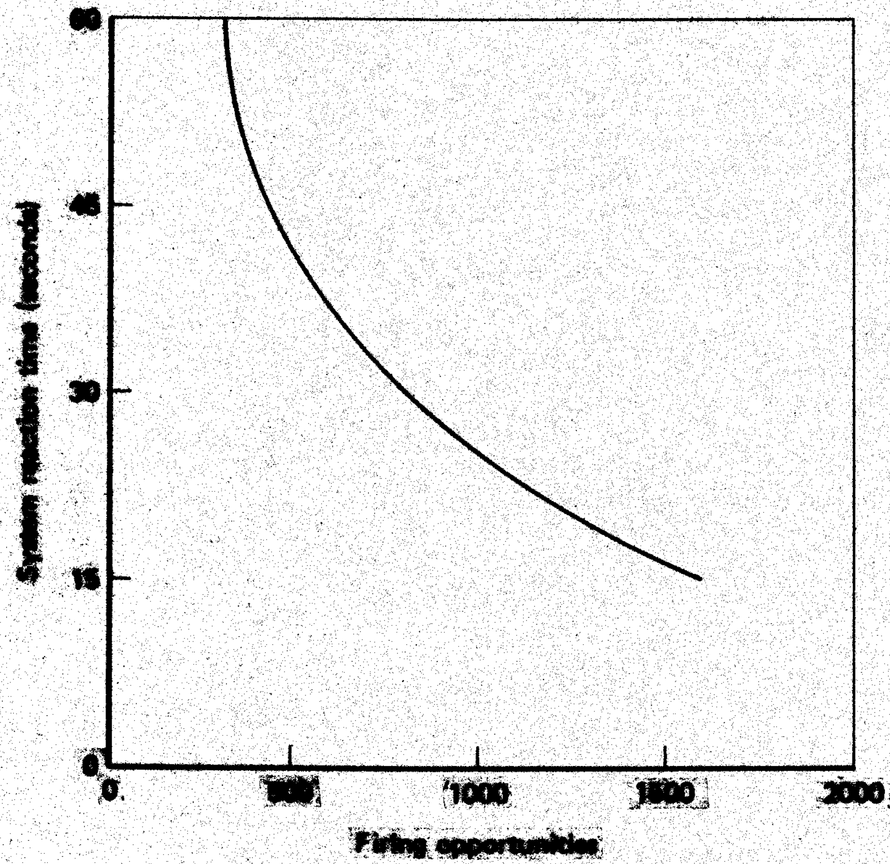

Fig. 8 — System reaction time vs. firing opportunities

for the initial positions of the TALLBOY force, the decrease in firing opportunities as system reaction time increases.

Since system reaction time includes target acquisition, the decision to fire, and munition launch and time of flight, any increase in the time required for any one of these events will reduce firing opportunities. Several aspects of this relationship were influenced by tactical and technological factors. One tactical factor was the decision time of the operators of the system. The ideal situation would be the immediate translation of target acquisition into a launch action--that is, having a direct connection between "eyeball" and "trigger." Any condition that delayed operator response, such as waiting for more targets to appear, processing targets, adjusting equipment, reporting combat information, and coordinating with other weapons, increased system reaction time and decreased firing opportunities.

Some ways to shorten the time between target acquisition and weapon launch were incorporated in the defense force. Technologically, for the indirect-fire systems, they were conceptualized as essentially *closed-loop* systems, with the acquisition portion--the elevated sensor--closely tied to the weapon either by being in the same vehicle (TALLBOY) or by having the sensor/command vehicle directly linked to the weapon vehicle (the guided mortar) in which the operator could automatically orient the mortar.

To enhance the closed-loop aspect, the tactical concept envisioned units capable of semiautonomous operation. Each unit in the defense area had an assigned sector of responsibility within which it could deliver fire as required, with minimum coordination with other units and organizational echelons. Although this resulted in some "overkills," a factor discussed later, it provided the potential for a short reaction time.

The desire for swift reaction also influenced the nature of the systems used in the force. The two indirect-fire systems were short-range systems, primarily because a short time of flight was desired in order to take advantage of the many short stretches of open terrain in the area.

Battle intensity was thus largely determined by a combination of tactical and technological factors in the two evaluations. Although the particular results were derived from the particular combat situations and systems used in the evaluation, the *general* characteristics of the systems as they affected the combat exercise hold clear implications for future conventional combat in Europe. It is reasonable to assume that targets will be acquired at greater ranges as the technology of ground (or air) surveillance and target acquisition systems advances. Such advances, when combined with precision munitions delivery and with the development of effective means for rapidly tying in target data to weapons (closed-loop operations), will heighten combat intensity--all the more so if the enemy's tactical doctrine emphasizes mass and momentum.

SYSTEM SYNERGISM

System synergism, a multiplicative factor arising from the interdependence and cooperation between systems, was continually demonstrated in the study. An example can be seen in Fig. 9, which indicates vehicle kills achieved by both the direct- and indirect-fire systems in the guided mortar evaluations; somewhat similar results occurred in the TALLBOY evaluation. The figure shows that the guided mortar scored most of the longer-range kills, and the direct-fire system scored most of the shorter-range kills. This complementarity did not result from differences in the ranges of the weapon systems, because these were the same, but from the mode of employment. It is a striking illustration of the adaptation of technical capability to tactical plans.

A few other examples of synergism are presented here to indicate the scope of the interactions between tactics and technology. One example is in the air defense play of the battles. The direct-fire weapons could be used in an air defense mode. The five-kilometer range of the weapon was, in fact, as much influenced by the requirement that it have an air defense capability as by the antivehicle requirement. Using the magnification sight, the weapon could track aircraft and helicopters, and the short time of flight enhanced its capabilities to achieve a kill.

By contrast, the indirect-fire systems had no air defense capability. When RED's helicopters attempted to locate and attack these systems, however, their attacks were neutralized by the large number of direct-fire weapons in the area.

Synergism was also manifest in the use of BLUE artillery. BLUE used his artillery primarily to deliver smoke and lay fields of mines along open routes of the enemy advance. The minefields in turn enhanced the effectiveness of the indirect-fire systems by slowing the enemy and thus increasing firing opportunities. Mines were used more for that purpose than for directly knocking out enemy vehicles. The effect of decreasing the speed of the RED vehicles on firing opportunities is illustrated in Fig. 10 for various platform heights of the guided mortar force.

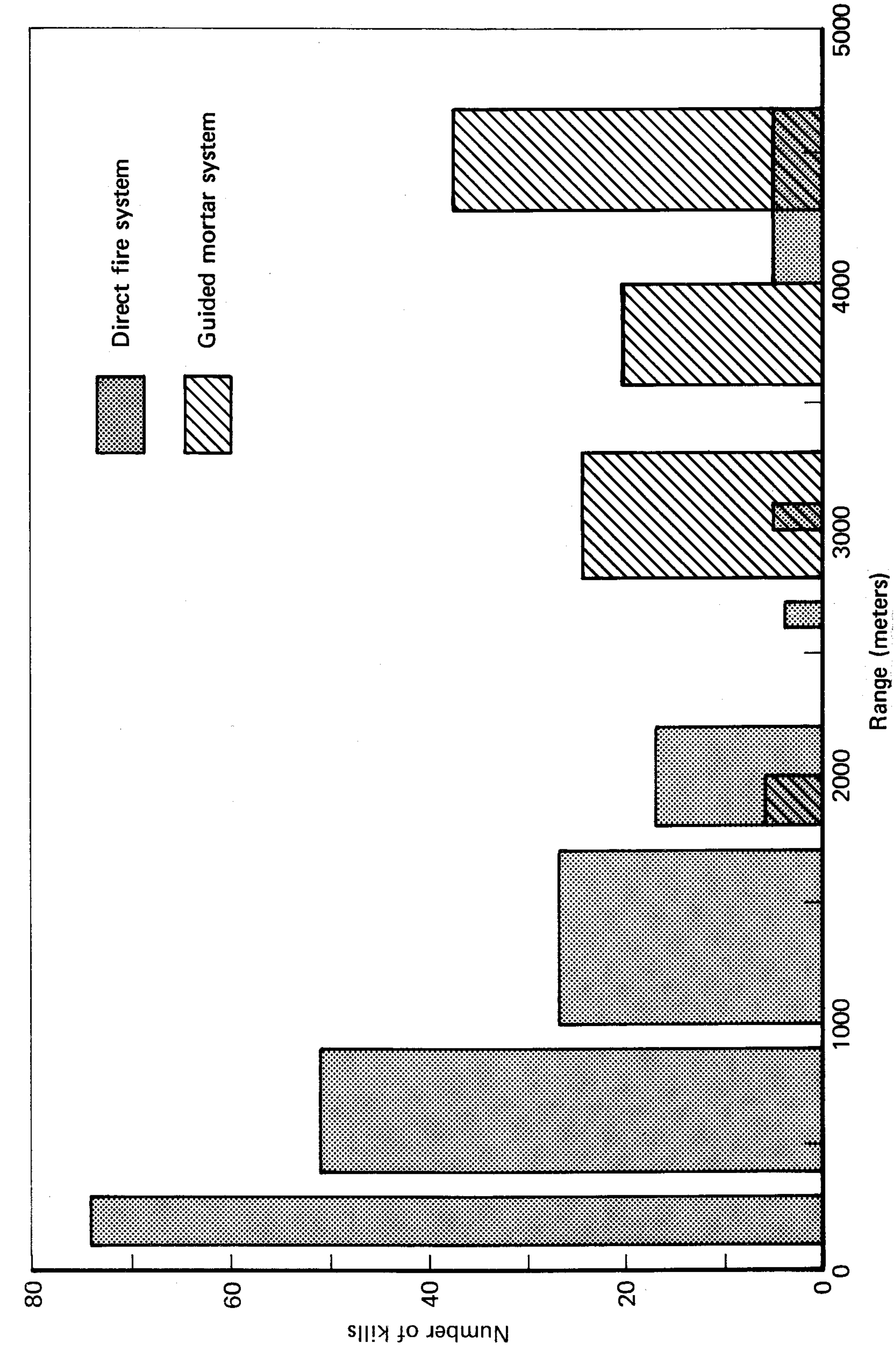

Fig. 9 — Kills vs. range

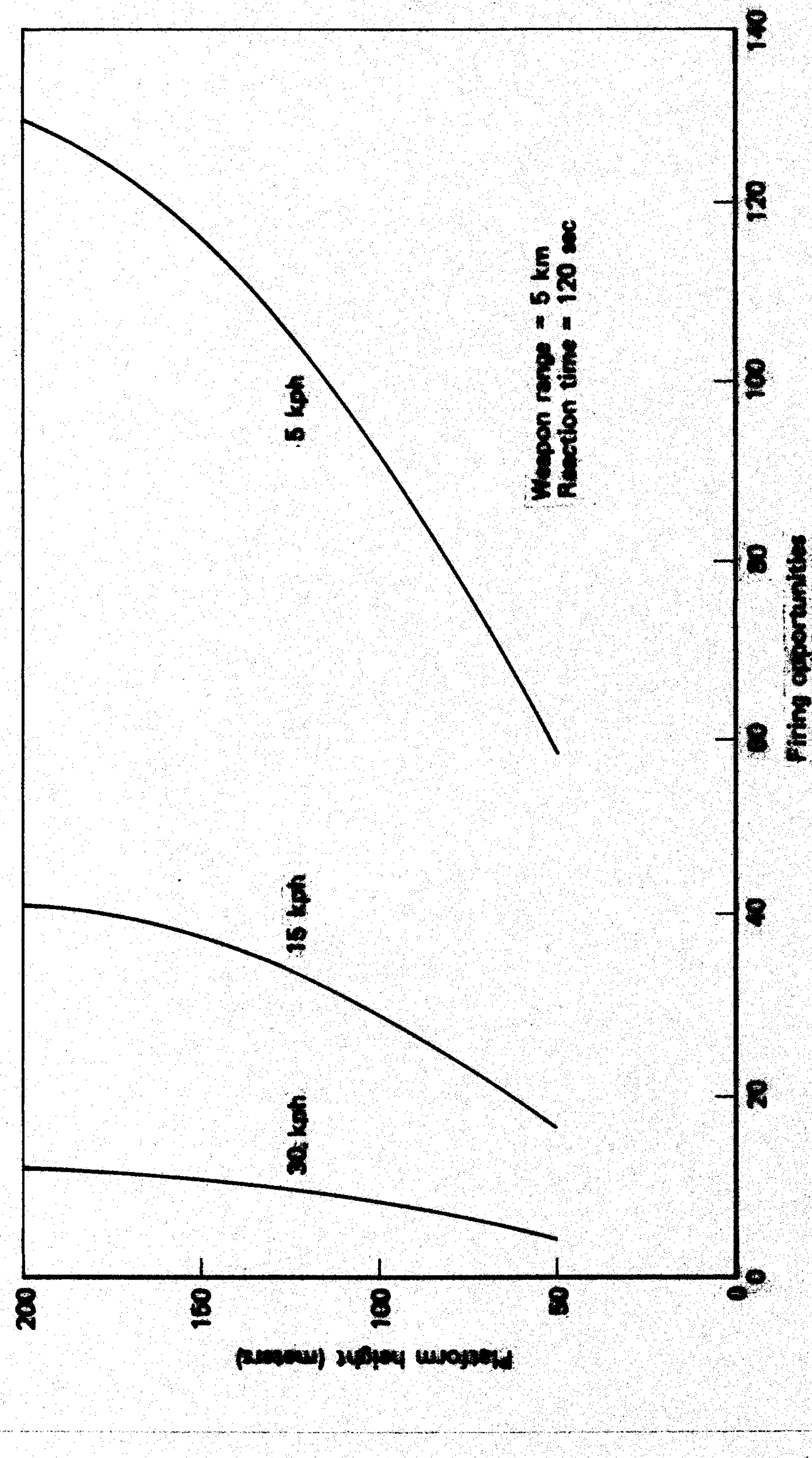

Fig. 10 — Firing opportunities vs. target velocity for different platform heights

The figure shows that reducing the average velocity of the enemy units to 15 kph or down to 5 kph because of either the presence or expectation of mines increased the number of firing opportunities at all platform heights. The effect became more pronounced at the greater heights, which gave greater range and coverage to the indirect-fire systems. BLUE was not able to reduce RED movement to such low speeds throughout the battle. His mines were especially effective on long open stretches that RED had to transit. The consequence was that the combined technical capabilities of the artillery and the guided mortars were more effective than the sum of their individual contributions.

As a final example of system complementarity, the information obtained from the coverage of the elevated sensors was used as a basis for moving the direct-fire units to areas of high threat in order to concentrate fire in these areas.

The examples of synergism and complementarity just enumerated are unique to these particular systems, but synergism is a basic premise of all "combined arms" forces. It is one means of achieving flexibility to deal with a variety of contingencies. What the evaluations highlight is that synergism is a *force* consideration. As technology continues to offer the prospect of new systems, the choice of which ones to procure will increasingly have to be viewed in the *force* context rather than solely in terms of individual system characteristics.

Even when several different systems provide a mix of complementary capabilities, the number of each type in the mix is seldom clear. The questions of "what should be given up" and "how many of what types to have in the force" become increasingly important for forces that utilize advanced technology. In the future, deciding what constitutes the "best" balance of different capabilities will require an increased understanding of the synergistic contributions of new systems.

COMMUNICATIONS

Synergism was a critical aspect of both battles. In almost every action, synergism was evident between systems, systems and tactics, or systems, tactics, and organizational structure. The multidimensional synergistic effects of these battles serve only as illustrations of a requirement that will become increasingly important in future combat as weapon systems of greater capability are introduced. This is the requirement to "orchestrate" tactical, organizational, and technological capabilities in a high-intensity battle.

Such orchestration places a high premium on communications. Communications have always been the "glue" that makes organized combat possible, and they become crucial as battle intensity increases and available resources must be used at top efficiency.

In the two battles, explicit emphasis was placed on having systems operate as autonomously as possible, primarily by the use of designated sectors of responsibility. Even under these circumstances, the importance of lateral (between units) and vertical (to higher headquarters) communications was continually evident. Because of the fast tempo of the battles, the status and locations of BLUE and RED forces changed rapidly, and the firepower and maneuver of units had to be continually coordinated. For the study, a distinction was made between the "information flow" necessary for carrying out combat operations, and "communications" as the mechanism for transmitting the information. The study dealt only with information flow. No attempt was made to deal with devices, message formats, or system architecture for communications. The examples therefore deal only with information flow.

In the battles, the semiautonomous mode of operation was initially achieved by allowing units to engage any targets within their assigned sectors of responsibility. As the battle progressed, units were either lost or they displaced to new locations because of the enemy advance. To maintain coverage of the area, the information on losses and displacements had to be transmitted to the force headquarters, evaluated, and passed on to other units so that they could cover any gaps or holes in coverage that the enemy might exploit. As the battles progressed and unit movements became more frequent, the amount of information passed vertically increased considerably.

Similarly, when several units were covering the same area, they could concentrate their fire on targets moving in the area. When the coverage of an area increased, so did the possibility of several systems firing on the same target. For efficient fire allocation in such situations, information on which units would engage which targets was necessary in order to avoid overkills and waste of munitions. This required the lateral transmission of information between defense units throughout the battle. In view of the fast tempo and the desire to use the closed-loop capability of the indirect-fire systems to keep system reaction time as low as possible, the lateral information flow had to be both rapid and detailed enough to allocate fire against specific targets.

More than other modes of defense, the DAD concept probably has a greater requirement for lateral information flow to coordinate the allocation of fire and for vertical information flow to maintain continual coverage of the area. In the future, however, any form of high-intensity combat will require close orchestration, and will depend more heavily on the rapid passage of *relevant* information, both laterally and vertically. In addition to the technological implications, the growing dependence on communications for orchestration will increase the demands on combat personnel, contribute to overloading the operators of advanced systems, and result in degraded performance, particularly under the stress of combat. Preventing personnel overload in combat may well become as critical a challenge as improving target acquisition and precision delivery of weapons.

RED COUNTERMEASURES

The preceding topics have dealt with tactical and technological considerations for the BLUE force.

The RED attack plan was based on prior knowledge that BLUE was using a distributed defense. RED also had information on the size of the defense force and the capabilities of BLUE's defense systems. His major uncertainty was the location of the BLUE defense positions.

In his attack RED used several tactical-technological means to limit the effectiveness of the BLUE defense. A few are described here by way of illustration. One of the ground rules laid down for the exercise was that RED could not spring any "technological surprises"--any purely hypothetical technical developments that would have negated the BLUE defense sytems, such as devices that would counter a laser or that would prevent moving vehicles from generating an IR signature. RED's systems were therefore within the current state of the art.

RED's attack plan called for extensive use of artillery to suppress and harass the BLUE defense. He modified the conventional use of artillery in several ways because of his military appreciation of the BLUE defense. The initial use of artillery was to target likely areas that might be occupied by BLUE direct-fire systems, because RED gave these systems a high priority. BLUE was expected to move them out of danger once they came under fire. RED was as much interested in forcing BLUE to move as he was in killing the systems since the BLUE indirect fire systems were then out of the battle for as long as it took them to retract their elevated sensors and move to new positions, which cut down on RED's losses when he had to cross stretches of open area. This use of artillery, which was effective in a number of instances, also involved RED's placing a few artillery volleys on a large number of likely BLUE positions rather than many volleys on a few positions. RED's use of artillery therefore was partly his tactical-technological response to the three components of the BLUE triad: the lethality of the BLUE indirect-fire systems (technology), the positioning of the systems to cover open areas (tactics), and the use of small units (organization) capable of displacing quickly if they came under fire.

Artillery was also used effectively on targets of opportunity. In some locations, observers from maneuver units were sent forward to high points to detect, locate, and call for artillery fire on BLUE's elevated sensors. RED also used large amounts of artillery-delivered and rocket-delivered smokescreens when moving across open areas.

As another tactic, RED coordinated his artillery fire with the movement of his vehicles across open areas. He "walked" his artillery fire along the immediate flanks of the moving vehicles to create clouds of debris and "hot" explosions as a means of degrading the BLUE laser and IR systems. When a RED column was moving along a forest route, antipersonnel artillery was occasionally used on likely BLUE direct-fire positions to produce casualties or degrade the performance of the direct-fire unit, which had to be exposed while firing.

RED also used his attack helicopters, another part of his force, in tree-level sweeps to try to detect elevated sensors and to attack the indirect-fire vehicles. RED helicopter losses increased when BLUE countered by moving direct-fire units into the area to provide local air defense for some of the BLUE indirect-fire positions.

RED maneuver units employed a number of tactics for attacking or degrading the effectiveness of the BLUE defense. In crossing some open areas, RED vehicles moved in a line abreast rather than in columns, in an attempt to reduce the time available for target acquisition by the BLUE systems. On several occasions, RED detached personnel carriers from their parent units and sent them into likely BLUE indirect-fire positions. In several situations when RED was moving through an area of likely defense positions for direct-fire ambushes, RED units conducted reconnaissance by fire as they proceeded.

Overall, RED integrated his fire and maneuver capabilities in a concerted effort to destroy, neutralize, or degrade the effectiveness of the BLUE defense systems. In addition, RED surprised several BLUE units on the road as they displaced to new defense positions. No single tactic or capability dominated RED's plan, but they were effective enough in combination to enable him to reach his objective, albeit with heavy losses.

The ground rules for the exercise did not permit the full range of possible RED responses to BLUE's defense posture because some of them--nuclear and chemical weapons, for example--would have altered the tactical situation so drastically as to preclude adequate evaluation of the defense systems. For the same reason, the use of dismounted RED infantry to sweep the entire defense area was not played, since it would have nullified the purpose of the exercise. Instead of putting his advanced weapon systems to the test, BLUE would find traditional response more appropriate: moving BLUE infantry and tank forces into the forward area, or launching attack helicopter or tactical aircraft sorties against RED's infantry, while ordering BLUE direct-fire units to withhold air defense fire to avoid fratricidal kills.

In general, RED's "countermeasures" were a direct response to the nature of BLUE's defense concept, tactics, organization, and technology.

They are of interest primarily because they emphasize the importance of considering the interactions between tactics and technology not only for friendly forces, but for their influence on the enemy's tactical-technological responses.

SUMMARY

This section has presented a series of examples and observations on interactions between tactics and technology based on a specific defense concept involving specific systems in a specific combat situation. They illustrate that these interactions are complex and diverse. Although their precise nature, magnitude, and significance will always be highly dependent on the specifics of the tactics and technology, the study also suggests something of the general character of tactical-technological interplay for future combat. The next section presents some broader generalizations and speculations on these aspects.

III. GENERALIZATIONS AND SPECULATIONS

Using the two evaluations discussed above as a point of departure, this section presents a series of generalizations and speculations about future ground warfare in Europe. These generalizations and speculations have the following limitations:

- They are based on only two situations in which a new defense concept, advanced systems, and specially designed tactics were employed.
- They refer only to the European theater and derive from exercises peculiar to a specific geographic area in West Germany. While they may be typical of other areas or geographies, the evaluations offer no basis for assuming they necessarily will be.
- They are limited to ground operations in a conventional conflict. The introduction of nuclear, chemical, or biological weapons would drastically change the combat picture and hence the relevance of these observations.
- They are restricted to the next generation of military capabilities. Completely different capabilities in the more distant future may change the entire complexion of ground warfare.

For convenience, the generalizations and speculations are presented below as a series of separate items, although a number of them are interdependent.

COMBAT INTENSITY WILL BE HIGH

This point stems from a combination of at least three factors: improvements in weapon lethality, target acquisition capabilities, and mobility.

Lethality

In recent years, precision guidance has greatly improved weapon accuracy. Precision guided munitions (PGMs) will continue to improve in a number of ways. Developments in warheads will expand the types of targets against which they can be used. Developments in sensors will increasingly extend the spectrum of environmental conditions under which they can be used, so that night, smoke, and poor weather will not present significant limitations. The modes of employment will be expanded as "fire and forget" capabilities are developed, and as remote control of weapons becomes increasingly feasible. For indirect-fire PGMs the use of submunitions that home on target or are target-activated will be expanded.

These advances in precision munitions will become particularly important as munition time of flight decreases and the weapons can be effectively employed in most areas of Europe where rolling terrain, forests, and urban areas produce a richly varied pattern of alternating exposure and concealment for enemy forces on the move.

Improvement in precision guided weapons will impart a new dimension to weapon lethality. In many cases, it will allow use of smaller warheads and lighter munitions for an equivalent level of damage. The net effect can be a dramatic increase in the killing potential of units.

Target Acquisition

The gain in weapon lethality is further amplified when it is coupled with an increased capability to acquire targets. The current emphasis on improvements in both ground- and air-based surveillance and target acquisition systems will lead to increased coverage of the battlefield and rear areas, and an increase in the number of targets that can be acquired. The data on the elevated sensor systems used in this study's evaluations indicate the significance of improvements in that direction.

Improvements in target acquisition will be most effective, however, if they can be combined with a short system reaction time, particularly to take advantage of short stretches of open terrain. Short reaction times will be realized as technological developments produce a closer coupling between target acquisition and weapon delivery in closed-loop systems, and shorter times of flight for munitions.

Mobility

The degree of improvement in mobility promised by the next generation of battlefield systems is not of the same order of magnitude as that offered in the realm of target acquisition and lethality. It may be that the technology of mobility has reached something of a plateau with the development of modern combat vehicles and helicopters, and is destined to remain there for a good number of years. Mobility improvement is important nonetheless. Even modest increases in vehicle agility and reduction in size will affect battlefield operations.

A diverse array of consequences will flow from improvements in lethality, target acquisition, and mobility, but their overriding effect is likely to be acceleration of the tempo of combat.

COMBAT UNITS WILL BE SMALLER

The "appropriate" size of combat units will be a continuing organizational and tactical question as technology enables smaller units to achieve high lethality and mobility. Smaller units can displace more rapidly and concentrate firepower more rapidly. They are less vulnerable to an enemy who stresses massive use of artillery or resorts to nuclear weapons. Putting aside the issue of whether the increased intensity of conventional operations would make nuclear operations more or less likely in the European environment, the benefits of dispersion and lowered troop densities in such operations is well established. Currently, the practical limits on dispersion--dictated in part by the limitations in current weaponry, surveillance, and target acquisition devices--are a source of concern in the face of a mounting nuclear threat. The advent of longer-range target acquisition capabilities, coupled with precision delivered fire, may increase the feasibility of dispersion and distribution of units in the battle area for both nuclear and non-nuclear tactical operations.

EFFECTIVE BATTLE MANAGEMENT WILL BE CRITICAL

Technological advances in lethality, target acquisition, and mobility will necessitate closer orchestration of combat and support activities in high-intensity combat. The effective orchestration of the complex interrelations between tactics, organization, and technology is likely to extend beyond the more restrictive notions of command, control, communications, and intelligence (C^3I) to the broader notion of "battle management". The coordination of ground operations in high-intensity combat will require the integration of resupply, reconstitution, and other activities and assets, in order to develop the full combat potential of the force.

Battle management is likely to become all the more critical as the enemy improves his own tactical and technological capabilities. Combat intensity will accelerate as technology on both sides reduces the battlefield distinctions between day and night, good and poor weather, and forward and rear areas. As time and space become more compressed, the consequences of errors or failures in planning, tactical execution, equipment operation, and communications will become more critical. There will be less chance to learn during combat, and the dangers of trial-and-error at all levels will intensify.

The implications for both tactical and technological developments under these conditions are extensive and largely unexamined. New tactics will develop, with greater emphasis on both the amount of information required as well as its timeliness. And technology will be pressed to exploit information-handling requirements through automation, information display, decision aids, and the like. Changes in tactics will demand corresponding adjustments in the nature of the information required, the patterns of information flow, and the formatting of the information if effective battle management is to be achieved. Nowhere is the understanding of the interaction between technological advances and tactical employment more important than in the area of battle management.

TECHNOLOGICAL ADVANCES WILL PLACE GREATER DEMANDS ON HUMAN CAPABILITIES

It is almost axiomatic that improvements in technology result in more complex systems. But complexity is difficult to assess precisely. It can have at least two dimensions. One is *technical* complexity, commonly evident in the number of physical processes that are integrated into a functioning system. The other is *task* complexity--the demands that the system places on its operators.

Technical complexity will undoubtedly increase in military systems whether they be weapon systems, target acquisition systems, or systems that enhance battle management. They will incorporate complex processes of aerodynamic, optical, mechanical, electronic, and chemical events. The probability of failure increases with complexity, and highly complex systems are subject to "catastrophic" failure; that is, they are prone to degrade not gradually but totally. Malfunctioning systems turn into liabilities, not only because they degrade combat effectiveness but because they demand repair or retrieval. Vigorous efforts are being made to minimize this problem by heightening reliability through redundancy, modularity, and simplification in systems design.

Technical complexity does not necessarily mean greater complexity for the system operator. Designs for advanced systems are usually sensitive to human engineering. Nevertheless, advanced systems tend to require elite personnel with special operating skills, and the strain on operators will be all the more if battle intensity increases as it is expected to. The same principle applies to battle managers, who will have to make swift and effective decisions on force allocation and employment under the stress of time and space constraints.

In short, technological advance carries many implications for personnel selection, training, morale, and the need for a thorough appreciation of human capabilities and limitations.

MANEUVER OF FIREPOWER WILL INCREASE IN IMPORTANCE

The most prominent tactical feature of the concept evaluated in the study is captured in the term *distributed area defense*. Implicit in this concept is the notion that advanced technology will enable the defending force to apply firepower much more efficiently than is possible with current systems. The tactical manifestation is a scheme in which widely dispersed, relatively small units, distributed both laterally and in depth, seek to dominate a large area by taking advantage of two factors: the target acquisition capability of elevated sensor platforms and the precision of indirect-fire weapons.

Since the defending units in the study were small and their density low, one way to achieve needed mass once the attacker's plan was revealed was to *maneuver* firepower instead of combat units. This appears to be a highly effective strategy, whether or not combat units are employed in a distributed area defense.

In the future, as the coverage and precision of indirect-fire systems increase and as system reaction times are reduced, the concept of massing through the maneuver of firepower can be applied more broadly and could become the tactical mainstay throughout the defended area.

Mobility will continue to be important, of course, for there will always be practical limits to the effective range of tactical systems, and mobility reduces vulnerability to enemy countermeasures. In the extreme form, maneuver of firepower may be achieved by ground-based systems that have the requisite target information and are capable of delivering large volumes of precision fire while on the move.

Many aspects of this concept should be explored, since it has extensive technological and tactical implications. It also has broader implications for the size of the firepower units, the appropriate mix of firepower units and traditional maneuver units, and the vulnerability of firepower units to enemy countermeasures.

IN WARTIME, TACTICAL ADAPTATIONS ARE LIKELY TO BE MORE FEASIBLE THAN TECHNOLOGICAL INNOVATIONS

Both NATO and the Warsaw Pact recognize that a conventional conflict in Europe would probably be intense and heavily destructive in its initial stages, and there would be enormous pressure to limit its length and scope. Under these circumstances, both sides would have to depend primarily on the forces, tactics, and technology available at the time.

The shorter the conflict, the less chance there would be to develop and employ new technology. By contrast, the opportunities for tactical adaptations would be greater, though still limited because of the compression in time and space of the battles and the possibility of around-the-clock operations.

Even if the conflict lasted several months, flexibility would probably be much more a feature of tactics than of technology. Only a prolonged war might allow sufficient scope for the development and employment of dramatic technical innovations.

If these speculations are true, it clearly would be wise to gain a thorough understanding of tactical-technological relationships and capabilities before the conflict. There is little opportunity to "learn" in high-intensity conflict, and mistakes may inflict severe consequences.

MAJOR DEVELOPMENTS IN TACTICS OR TECHNOLOGY WILL HAVE A RIPPLE EFFECT ON FORCE STRUCTURE AND COMBAT OPERATIONS

The history of warfare is full of examples of the far-reaching repercussions of tactical and technological innovations. The advent of artillery and tanks changed not only the structure and organization of ground forces, but also the ways in which the forces were employed. Blitzkrieg tactics changed the ways in which ground forces were organized and equipped.

The Distributed Area Defense (DAD) concept used in this study may point the way to similar innovations. Although it was limited to an attrition operation forward of the main defense area, it is pertinent to ask how it might alter the larger defensive battle and what role, if any, the force might play in overall defense. Several alternatives are possible.

In the least complicated alternative, the survivors of the force would simply retire through the main battle area for recovery and reconstitution in the rear. The force would then have served only the specific function of attrition in the forward area, and might or might not be used later on. It would have been, in effect, a special purpose force with one primary mission.

In a somewhat more complicated alternative, the survivors would be amalgamated with the main defensive force, to which they would contribute their residual firepower. In this second alternative, the need to integrate a force having a dissimilar conceptual framework and capability with regular forces would almost certainly have broad tactical as well as technological implications.

A third, more radical alternative--in essence, a basic defensive variant--is also possible. This variant would seek to renew the attrition operation forward of the main battle area at opportune times, by taking advantage of delays that might be imposed on the commitment of the attacker's follow-on echelons. The defensive scheme would then require two adjuncts to the force defined in the study.

The first adjunct is an interdiction capability sufficient to delay entry of second and third echelon divisions into the battle for a matter of hours. During that delay, a maneuver force--the second adjunct--would try to regain control of the attrition zone. That done, the zone could be reoccupied by a new DAD force. This "accordion" concept involves a host of tactical and technological considerations at a much broader level than those discussed for DAD.

These three alternatives are presented merely to illustrate how innovations in tactics and technology can set a "ripple" effect in motion that will pervade many more components of the force than the ones where they were originally introduced. This ripple effect is often unforeseen. In the larger context, it can force recalculation of the appropriate mix of numbers and types of units in the force. It may even reopen questions regarding the balance of offensive and defensive capabilities, and of overall force structure.

SUMMARY

The foregoing discussion indicates that the interactions between tactics and technology raise a host of issues. This became apparent even within the narrow scope of the synthetic battles conducted for this study, which provided the basis for a number of generalizations and speculations, most of them related to the three basic characteristics of ground warfare: space-time relationships, firepower-maneuver relationships, and defense-offense relationships.

In terms of space-time relationships, technology offers improvements in lethality, target acquisition, and mobility. These improvements, particularly in a European conflict with an enemy whose doctrine stresses a willingness to incur heavy initial losses to achieve and sustain momentum, are likely to result in battles of high intensity, fought around the clock in good weather and bad, with little or no distinction between forward and rear areas. The resulting compression in space and time can be expected to influence defensive concepts, the size of combat units, the demands on combat personnel, and battle management.

In terms of firepower and maneuver, the improvements in technology will make it possible to concentrate accurate firepower at longer ranges in a shorter time. This may result in an increased emphasis on the maneuver of firepower rather than on the maneuver of combat units in defensive operations. The improvements will change not only the types of systems in the ground units, but may also change the types of units and the mix of firepower and maneuver systems.

In terms of defense-offense relationships, technological improvements are likely to benefit the defense more than the offense. This may impel changes in the balance between the two in the ground forces, in the ways in which they are integrated in combined operations, and in the nature and form of theater operations and support.

All of these observations point to the crucial need for a close partnership between tacticians and technologists.

THE TACTICIAN-TECHNOLOGIST PARTNERSHIP

Almost without exception, the observations and speculations of this section cut across the boundaries of the "neighboring disciplines" of the physical sciences, technology, and military science.

The term "tactician-technologist partnership" must be interpreted to embrace military professionals, scientists, engineers, and program planners. Their roles in the partnership are as diverse as their work, but it is useful to think of them as constituting three groups: those who stimulate (and fund) military technology; those who develop technology; and those who transform technology into military power in the field.

The partnership of technology and military science has long been important. It has been especially so in the last half of the twentieth century, a time in which the nation's military forces have been outnumbered by their possible adversaries, but also a time in which technology offers hope of redressing the imbalance. The two partners often have difficulty in matching their concerns, however.

Better than anyone else, military men know that military hardware alone cannot guarantee success in ground combat. Equally important are the organizations and tactics of the military units equipped with the hardware. A significant change in either tactics or technology is likely to call for a change in the other, or at least a reexamination of their relationship. It is rarely obvious, however, exactly what changes should be made or how extensive they should be. Neither is it clear which partner, if any, should dominate in either the short or long run. Debating the issue may be an exercise in futility anyway; the close interdependence between the two is the salient consideration that should now command our attention.

It has become apparent that the full complexities of the partnership are revealed only when tactics and technology are observed in action, whether real or simulated with a military objective, an adversary force, and a physical environment. Only then can the military planner begin to establish rational goals for technology and to adopt reasonable expectations about the benefits of technology. And only then can the technologist thoroughly comprehend what is required of his technology.

These are general statements of principle upon which the partnership would seem to be in general agreement. Yet the fact remains that there are imperfections in the way in which the partnership pursues military technology, chooses among technological alternatives, and integrates the technology/tactical matrix.

Sometimes the military planner is too ambitious in specifying characteristics for new equipment and setting performance goals. This can result in systems that are more costly than they need be, or in the waste of technological time and effort expended on unattainable goals, or in inordinately long development times. Conversely, he sometimes fails to see the promise of this or that technological development, and misses opportunities for real improvements in military capabilities.

The technologist, for his part, immersed in his discipline and often working at the forward edge of the state of the art, may fail to perceive the gulf between promising laboratory results and feasibility in the field. He may then accuse his military counterpart of obtuseness for not seizing upon his product. Or he may fail to realize that the military worth of his technological "solution" depends upon concomitant developments in other areas of technology or in tactics, over which he has no control. In such cases, he may find that he has wasted precious research effort and time. And, unwittingly, he may actually compound the problem faced by his military client if he induces the client to explore proposals that prove to have little or no current or foreseeable utility.

The crucial question, then, is how to bring these two areas of expertise into closer conjunction so that they complement and reinforce each other. How are they to choose wisely between competing alternatives in research, advanced development, and engineering development? And how are the tactical and organizational concomitants of technological change to be understood and perfected?

One might think that, having lived with these concerns for the past three decades and more, the military-scientific-technological community would have found ways of dealing with them systematically. And, indeed, the community has been largely successful in this regard where the comparatively new but untested concerns of strategic warfare and strategic technology have been at issue. The modesty of its successes in the field of tactical operations, however, should cause military planners and technologists alike to press for a full and mutual appreciation of the interactions between tactics and technology.

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